Swashzone Processes

Britt Raubenheimer
Woods Hole Oceanographic Institution
266 Woods Hole Rd., MS #12
Woods Hole, MA 02543
phone: (508) 289-3427 fax: (508) 457-2194 email: britt@whoi.edu

Award Numbers: N00014-99-1-0193, N00014-00-1-0378

LONG-TERM GOALS

The long-term goal is to develop and verify models for fluid and sediment processes in the swash zone.

OBJECTIVES

The specific objectives of these projects are to:

- compare model predictions with observations of wave-driven setup collected during the SandyDuck experiment

- observe and model swashzone fluid velocities

APPROACH

Comparisons of observations and model predictions are being used to investigate swashzone processes, including the wave-driven setup that affects the swashzone location, and the runup fluid velocities that are important to sediment transport.

The theoretical balance (Longuet-Higgins and Stewart, 1961) between cross-shore gradients of the mean water level and the wave radiation stress is being evaluated using observations of wave-driven setup. Setup observations were acquired during the SandyDuck experiment from Sept. through Nov. 1997 on a sandy Atlantic Ocean beach near Duck, NC. Bottom pressure was measured with 12 buried pressure gages located between the shoreline and about 5-m water depth. The setup pressure sensors were buried to avoid flow-induced deviations from hydrostatic pressure.

Over the next few years, field and laboratory experiments will be conducted to obtain observations needed to test models for swashzone fluid velocities. Even though runup excursions owing to random waves on a natural beach are modeled well by a model (Rbreak) based on the vertically-averaged nonlinear shallow water equations with quadratic bottom friction (Kobayashi et al. 1989, Raubenheimer et al. 1995), it is not clear whether the cross-shore velocity u is predicted accurately. Field measurements will be collected during fall 2000, and laboratory observations will be obtained during 2001 and 2002. The observations will be compared with Rbreak-predictions, and predictions from the model extended to include a parameterized bottom boundary layer.

Report Documentation Page	*Form Approved OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
SEP 2000		**00-00-2000 to 00-00-2000**

4. TITLE AND SUBTITLE **Swashzone Processes**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution,,266 Woods Hole Rd., MS #12,,Woods Hole,MA,02543**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

Wave-driven setdown and setup observed during SandyDuck have been compared (Raubenheimer et al. 2000) with a model based on the theoretical setup balance (Longuet-Higgins and Stewart 1962). After correcting for temporal changes in water density (Lentz and Raubenheimer 1999) with conductivity and temperature measured in 5-m water depth, mean water levels were calculated from 512-s (8.5-min) records by assuming hydrostatic pressure. Drifts owing to changes in the pressure gage offsets (equivalent to about 0.03 m of water over the 3-month experiment) were removed from surfzone observations by subtracting a quadratic curve fit to setup estimated during small (nonbreaking) wave conditions when negligible setup or setdown was expected. In the swashzone, drifts were removed by adjusting the calculated mean water levels so that the water levels equaled sand level when the saturated sand above swashzone sensors first was exposed during rundown (Raubenheimer et al. 1995). Setup (setdown) was defined as the increase (decrease) of the mean water level relative to that observed at the most offshore setup sensor. The observed shoreline setup was estimated as the setup where the total water depth was less than 0.1 m. Observations were compared with predictions of the setup balance integrated numerically using a 4th-order Runga-Kutta scheme with an adaptive step size for all 512-s data records.

Preparation for the SwashX field experiment at Scripps beach, including testing of new acoustic current meters, is underway. Five 3-dimensional acoustic Doppler velocimeters (ADV), two sets of three 2-dimensional ADV cable probes stacked vertically 2, 5 and 8 cm above the bed, and a pulse-coherent acoustic Doppler profiler (PC-ADP) will be deployed along a cross-shore transect spanning the swash and inner surf zones (Figure 1). Collocated pressure sensors will be buried just below sand level to measure runup heights. Frames have been built, sensors have been calibrated, and software for real-time data acquisition and display is being written.

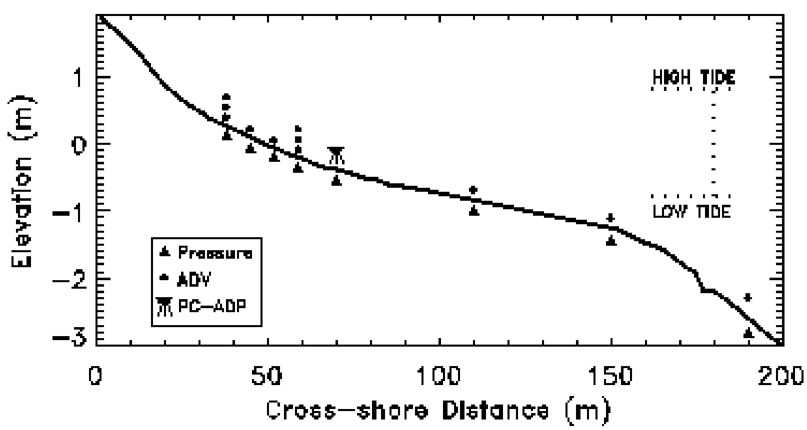

Figure 1: Beach profile and targeted instrument locations.

RESULTS

The observed setdown, the depression of the mean water level seaward of the surf zone, is predicted well (Figure 2) when radiation stresses are estimated from the observations using linear theory at each location along the transect. The observed setdown also agrees with analytical predictions based on offshore wave observations and the assumption of linear, dissipationless, normally incident waves

shoaling on alongshore homogeneous bathymetry. The observed setup, the superelevation of the mean water level owing to wave breaking, is predicted accurately in the outer- and mid-surf zone, but is increasingly underpredicted as the shoreline is approached (Figure 2C).

During each tidal cycle, the setup observed at a fixed surfzone location is larger at lower tide when the observation location is closer to the shoreline (compare the three symbols for $x \geq 375$ m in Figure 2B with those in Figure 2C). With approximately constant incident wave height, the setup observed at $x = 390$ m increases from 0.03 m at high tide to 0.23 m at low tide, as the tidal elevation decreases by 0.9 m (Figure 2). It has been suggested that cross-shore profiles of setup (normalized by the offshore wave height) can be parameterized as a function of the local water depth (normalized by the offshore wave height). However on barred profiles, the setup often is different at locations on the outer slope of the bar, in the trough of the bar, and on the foreshore even though the water depths are identical, as shown in Figure 1C at the three locations ($x = 338$, 363, and 383 m) where the depth is 1 m.

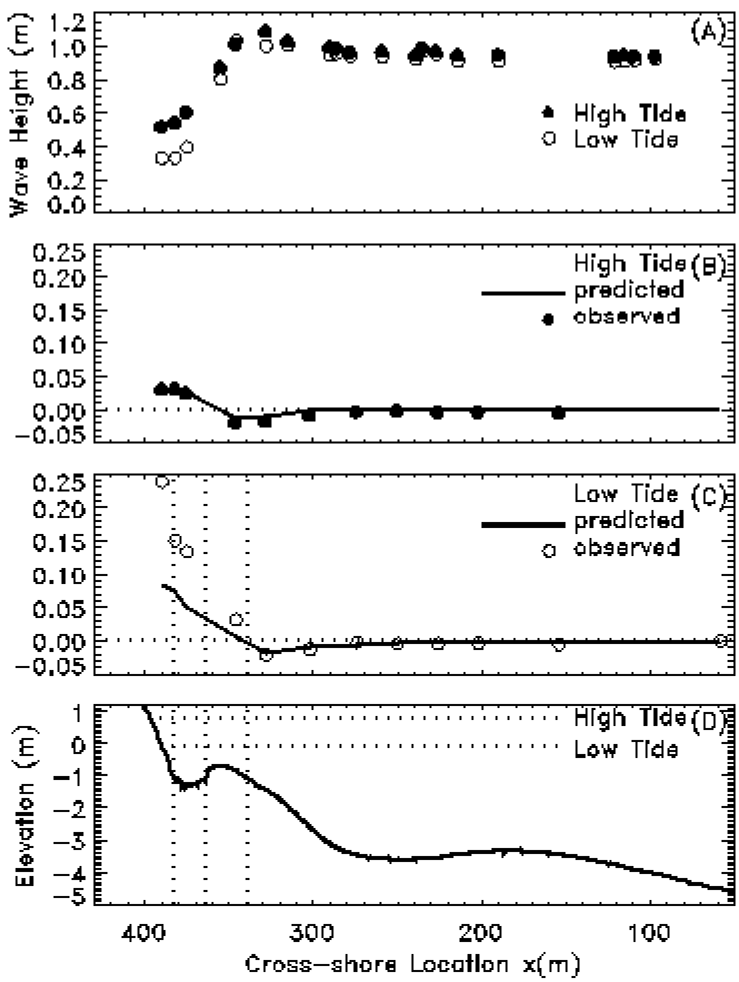

Figure 2: (A) Observed significant wave heights measured on Sept. 13, (B and C) observed (open circles) and predicted (solid curve) setdown and setup on Sept. 13 at (B) high tide (16:00) and (C) low tide (20:42), and (D) measured beach profile versus cross-shore location (times represent the start of each 512-s record). The vertical dotted lines in (C) and (D) mark the locations x = 338, 363, and 383 m discussed in the text. The horizontal dotted lines in (B) and (C) are still water level. The horizontal dotted lines in (D) are tidal elevations during the two runs.

Numerical simulations and the observations suggest that setup near the shoreline depends on the bathymetry of the entire surfzone and increases with decreasing surfzone beach slope β_{av}, defined as the ratio of the surfzone-averaged water depth to the surfzone width. Consistent with previous observations and empirical formulas, the observed shoreline setup η_{shore} increases with increasing offshore wave height $H_{s,o}$ (Figure 3A). However, scatter about the least squares linear fit is substantial. Better predictions of $\eta_{shore}/H_{s,o}$ result from a least squares linear fit to β_{av}^{-1} or to a surfzone Iribarren number $\beta_{av}\sqrt{L_o/H_{s,o}}$. In contrast to previous observations, the correlation of $\eta_{shore}/H_{s,o}$ with an Iribarren number in which β is equal to the foreshore slope is not statistically significant.

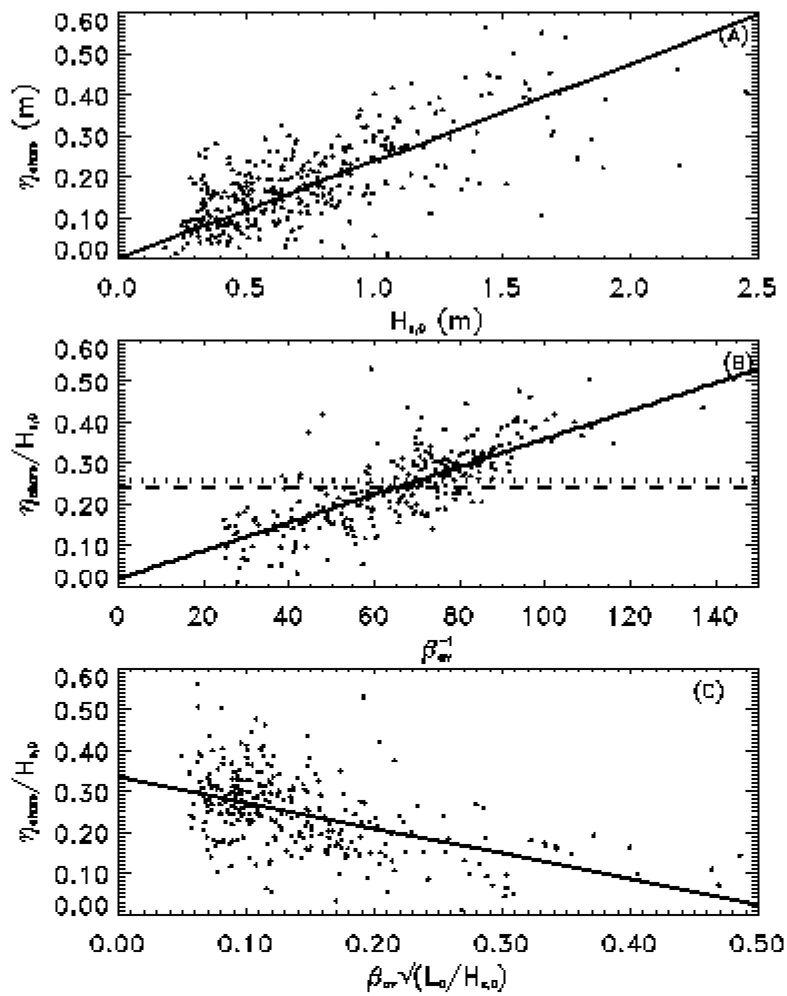

Figure 3: (A) Observed shoreline setup versus offshore significant wave height, and (B and C) observed shoreline setup normalized by offshore significant wave height versus (B) β_{av}^{-1} and (C) $\beta_{av}\sqrt{L_o/H_{s,o}}$. The solid line in (A) and the horizontal dashed line in (B) are the least squares fit to $\eta_{shore} = cH_{s,o}$, where c = 0.24 (root-mean-square(rms) error 0.10). The horizontal dotted line in (B) is the average normalized setup $(\eta_{shore}/H_{s,o})_{avg} = 0.26$ (rms error 0.10). The solid lines in (B) and (C) are the least squares linear fits given by: (B) $\eta_{shore}/H_{s,o} = 0.019 + 0.003\,\beta_{av}^{-1}$ (rms error 0.06); (C) $\eta_{shore}/H_{s,o} = 0.336 - 0.628\,\beta_{av}\sqrt{L_o/H_{s,o}}$ (rms error 0.08). Root-mean-square differences of 0.02 are statistically significant at the 98% level.

IMPACT/APPLICATIONS

The observed and predicted setup in shallow water decreases with increasing average surfzone water depth, implying that wave-driven setup may be reduced as sand bars move offshore into deeper water. However, the underprediction of setup in shallow water suggests caution should be used when estimating shoreline setup on natural beaches with models based on the Longuet-Higgins setup balance.

RELATED PROJECTS

Observations from the in situ sensors in SwashX will be used to evaluate estimates of swash and surf zone velocities from a video-based PIV technique (T. Holland, Naval Research Laboratory), and from FOPAIR (S. Frasier, U. Mass. Dartmouth).

REFERENCES

Kobayashi, N., G.S. DeSilva, and K.D. Watson, Wave transformation and swash oscillation on gentle and steep slopes, *J. Geophys. Res., 94*, 951-966, 1989.

Lentz, S., and B. Raubenheimer, Field observations of wave setup dynamics, *J. Geophys. Res., 104*, 25,867-25,875, 1999.

Longuet-Higgins, M.S., and R.W. Stewart, Radiation stress and mass transport in gravity waves, with application to 'surf-beats', *J. Fluid Mech., 13*, 481-504, 1962.

Raubenheimer, B., R.T. Guza, S. Elgar, and N. Kobayashi, Swash on a gently sloping beach, *J. Geophys. Res., 100*, 8751-8760, 1995.

Raubenheimer, B., R.T. Guza, and S. Elgar, Field observations of wave-driven setdown and setup, *J. Geophys. Res*., submitted, 2000.

PUBLICATIONS

Elgar, S., R.T. Guza, W.C. O'Reilly, B. Raubenheimer, and T.H.C. Herbers, Wave energy and direction observed near a pier, *J. Water Ports Coastal Ocean Eng*., in press, 2000.

Raubenheimer, B., R.T. Guza, and S. Elgar, Field observations of wave-driven setdown and setup, *J. Geophys. Res.*, submitted, 2000.

Elgar, S., B. Raubenheimer, and R.T. Guza, Current meter performance in the surf zone, *J. Atmos. Ocean Tech.*, submitted, 2000.